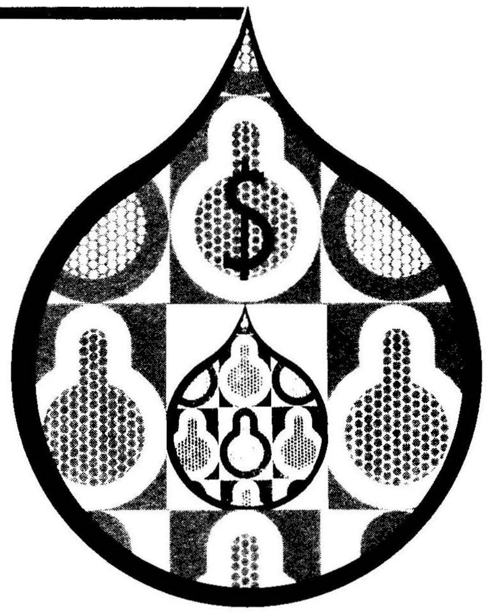

COST OF DRIP IRRIGATION FOR PAPAYA HAES Pj462

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Hawaii Agricultural Experiment Station · College of Tropical Agriculture and Human Resources · University of Hawaii

DEPARTMENTAL PAPER 63

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INTRODUCTION

Recent advances in drip irrigation technology offer timely opportunities for papaya farmers in Hawaii to realize potentially significant economic gains. Technical feasibility studies clearly show that irrigation efficiency can be considerably improved with drip irrigation.1/ The possibilities exist not only for increasing productivities2/ in terms of both quantity and quality of yield per acre on lands currently in traditional production but also to increase total production through acreage expansion into otherwise nonproductive marginal lands.

Greater irrigation efficiency and adaptability to otherwise marginal soils and terrain are possible because water can be applied directly to the root zone in the right amounts and timing for optimum production. Water wastage from deep seepage and run-off, and the constraining effects of moisture stress in the root zone can be effectively minimized. In addition, application of plant nutrients and supplements can be integrated into an efficient irrigation-fertilizer program.

In spite of these and other technical opportunities, the actual response to adopting this new technology has been somewhat hindered by some remaining economic uncertainties. Part of these uncertainties relate to the lack of adequate cost and revenue data which are essential for conducting economic feasibility studies.

Different approaches are required to obtain these cost and revenue data. Costs are essentially a matter of input supplies, whereas revenues mainly concern demand for outputs. This study will concentrate on supply-costs, leaving the study of market revenues for a later time. Such a cost-oriented study can be a useful aid to both existing and potentially new papaya farmers in evaluating their actual costs of and in selecting criteria for adopting drip irrigation as an alternative to more traditional irrigation practices. Also, this study is useful in providing the basic technological and economic parameters for evaluating drip irrigation systems for orchard type production in general.

OBJECTIVES AND PROCEDURES

The general purpose of this study is to establish baseline information on the cost of drip irrigation for papaya farming in Hawaii. More specific objectives are:

1. To identify important parameters and develop computational procedures for estimating the costs of adopting drip irrigation systems for papaya farming in Hawaii;

2. To formulate a generalized model for evaluating the total annualized use costs of such a system, and

3. To demonstrate application of the model for the range of papaya growing conditions in Hawaii.

The general procedure is to define a hypothetical 10-acre papaya farm on lands that would be marginal for papaya production without irrigation. Actual field practices in Hawaii are drawn upon for this purpose. A drip irrigation system for this hypothetical farm is then designed and its general physical layout and component subsystems described. Following this, an estimate of the current (1978) costs of purchasing, installing, operating, and maintaining the various components of the system is made. Capital costs are reduced to annual equivalent terms for comparison and combination with the annual operating and maintenance costs. This is done for each of the subsystem components and the system as a whole in order to identify the major cost items and the overall cost structure. The computational procedures are then generalized into a model which can be easily adapted to the needs of papaya growers in different locations in the state.

A HYPOTHETICAL FARM

Our hypothetical farm lies on 10 acres of fairly flat land with soils generally suitable for papaya growing with irrigation. The farm lot is nearly level (1-3% slope) and rectangular in shape with dimensions measuring 400 ft. x 1,089 ft. Annual rainfall in the area is light and sporadic so that year-round irrigation is required for crop production. However, there is some periodic effective rainfall that might substitute for scheduled irrigation about 25 percent of the time. Irrigation water is available at the farm lot at a delivery pressure of 60 psi. The water, although clear and meeting all drinking water standards, is not of sufficiently high quality to use in a drip irrigation system without filtration.

Figure 1 shows the physical layout of the farm. The land area can be divided into "blocks" of any size to conform with the layout of an irrigation system and planting schedule. Papaya trees are planted 7 ft. apart in two staggered-row sets. The distance between rows in a set is 6 ft. and the width of the aisles between sets is 11 ft. A 15 ft. wide road runs around the margin of the lot.

These dimensions will vary with cultural practices for any location with a given farm scale and technology. Nevertheless, the spacing parameters themselves are of greater importance in formulating a computational procedure for calculating the number of trees per acre and, in turn, the total water requirements and irrigation system layout of the farm.

Trees Per Acre--Computational Procedure

A procedure for computing trees per acre can be formulated as follows:

$$\frac{\text{trees}}{\text{acre}} = \frac{\left(\frac{\text{trees}}{\text{row}}\right) \times \left(\frac{\text{rows}}{\text{set}}\right) \times \left(\frac{\text{sets}}{\text{total acres}}\right)}{(\text{total acres})}$$

where:

$$\left(\frac{\text{trees}}{\text{rows}}\right) = \frac{(\text{length}) \quad - \quad \begin{matrix}(\text{allowance for border} \\ \text{roads, windbreaks, etc.})\end{matrix}}{(\text{tree spacings within rows})} + 1$$

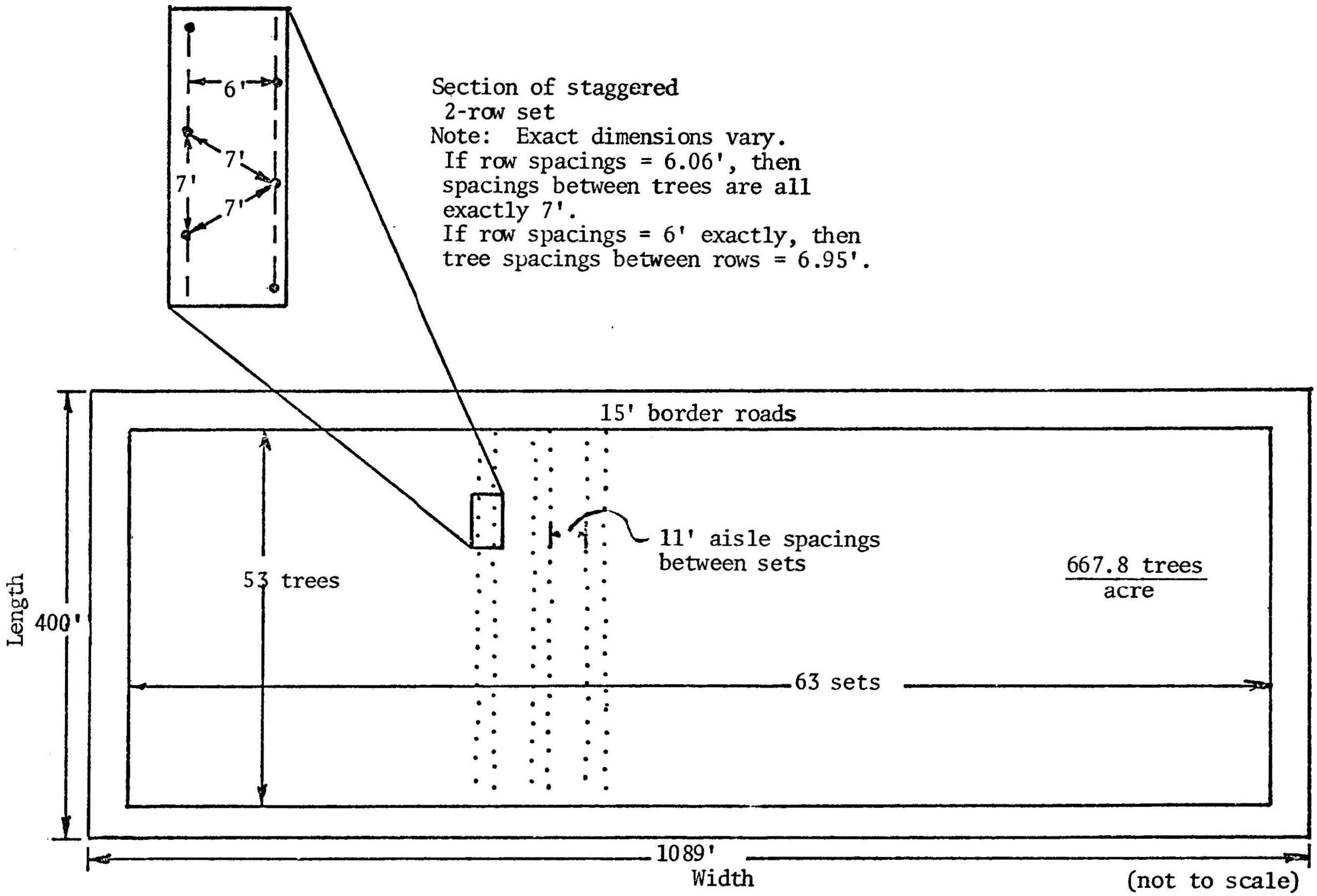

FIGURE 1: Hypothetical 10 Acre Farm

$$\left(\frac{\text{rows}}{\text{set}}\right) = \text{normally 2, unless single row plantings}$$

$$\left(\frac{\text{sets}}{\text{total acres}}\right) = \frac{(\text{width}) - \begin{pmatrix}\text{allowance for border}\\ \text{roads, windbreaks, etc.}\end{pmatrix} + \begin{pmatrix}\text{aisle spacings}\\ \text{between sets}\end{pmatrix}}{(\text{row spacings within set}) + (\text{aisle spacings between sets})}$$

Only rarely will the length and width dimensions of the total area be exactly used up. The remaining length (R_1) and remaining width (R_w) dimensions can be computed by difference as follows and reallocated throughout the farm.

$$R_1 = [\text{length}] - \left[\left(\frac{\text{trees}}{\text{rows}} - 1\right) \times \begin{pmatrix}\text{tree spacings}\\ \text{within row}\end{pmatrix} + \begin{pmatrix}\text{width of}\\ \text{border roads}\end{pmatrix} \times 2\right]$$

$$R_w = [\text{width}] - \left(\frac{\text{sets}}{\text{total acres}}\right) \times \begin{pmatrix}\text{row spacings}\\ \text{within sets}\end{pmatrix} + \left(\frac{\text{sets}}{\text{total acres}} - 1\right) \times \begin{pmatrix}\text{aisle spacing}\\ \text{between sets}\end{pmatrix} + \begin{pmatrix}\text{width of}\\ \text{border roads}\end{pmatrix} \times 2]$$

In the case of our hypothetical farm:

Parameter	Data
Total area	10 acres
Dimensions (length x width)	400 ft. x 1,089 ft.
Width of border roads	15 ft.
Aisle spacings between sets	11 ft.
Rows per set	2 (staggered)
Tree spacings within row	7 ft.
Row spacings within sets	6 ft.

$$\left(\frac{\text{trees}}{\text{acre}}\right) = \frac{\left(\frac{400 - 15 \times 2}{7} + 1\right) \times (2) \times \left(\frac{1{,}089 - 15 \times 2 + 11}{6 + 11}\right)}{10}$$

$$= \frac{(53) \times (2) \times (63)}{10}$$

$$= 667.8 \quad (\text{or } 6{,}678 \text{ trees}/10 \text{ acres})$$

The remaining length and width dimensions are:

$R_l = [400] - [(53 - 1) \times 7 + (15 \times 2)] = + 6$ ft. (surplus)

$R_w = [1{,}089] - [(63 \times 6) + (63 - 1) \times 11 + (15 \times 2)] = - 1$ ft. (deficit)

These remaining surplus and deficit dimensions can be reallocated to the perimeter roads or to whatever spacing adjustments deemed practical.

GENERAL LAYOUT AND DESCRIPTION OF THE DRIP IRRIGATION SYSTEM

The general layout of the drip irrigation system is divided into three subsystems: the main (including filter and siphon assembly), the submain, and the laterals (see Figure 2). A brief description of each subsystem follows:

Main

The main consists primarily of 3-inch PVC pipes and a filter-siphon assembly. A 100 ft. pipe length is allowed between the water source and the filter-siphon assembly. The rest of the main consists of 825 ft. of the same 3-inch PVC piping extending along one border of the farm. The entire main is buried underground at a depth of about 2 feet except for the filter-siphon assembly diagrammed in Figure 3.

A fertilizer-siphon assembly is added to facilitate the combining of fertilization and irrigation operations. Since the water supply source is potable, a backflow valve is required to prevent contamination. A basic drip irrigation system without a fertilizer siphon would require less parts. However, the total farm system might require additional inputs (e.g., mixing tanks, labor, etc.) to carry out the separate fertilization function.

Submains

Four submains are designed, each with sufficient capacity to easily serve the peak water requirements of 2.5 acres of trees. The PVC piping is reduced to 2 inches and continues underground at shallower depths but not less than 6 inches deep. Figure 4 shows the main-submain juncture which includes a gate valve, pressure gauge, and air relief valves. These parts are all exposed. To automate the system, battery operated Water Watcher valves can easily be installed in place of the manually operated gate valves. At appropriate 17 ft. intervals on the buried submain, 2 ft. lengths of 0.25 inch microtube "jumpers" are attached and connected to the laterals. About 280 ft. of 2-inch PVC piping are allotted to each submain.

Laterals

A half-inch flexible polyethylene pipe tubing is placed on the ground half-way between the two rows of a set. Each lateral is connected to the submain by the 0.25 inch microtube "jumper" and is terminated at the

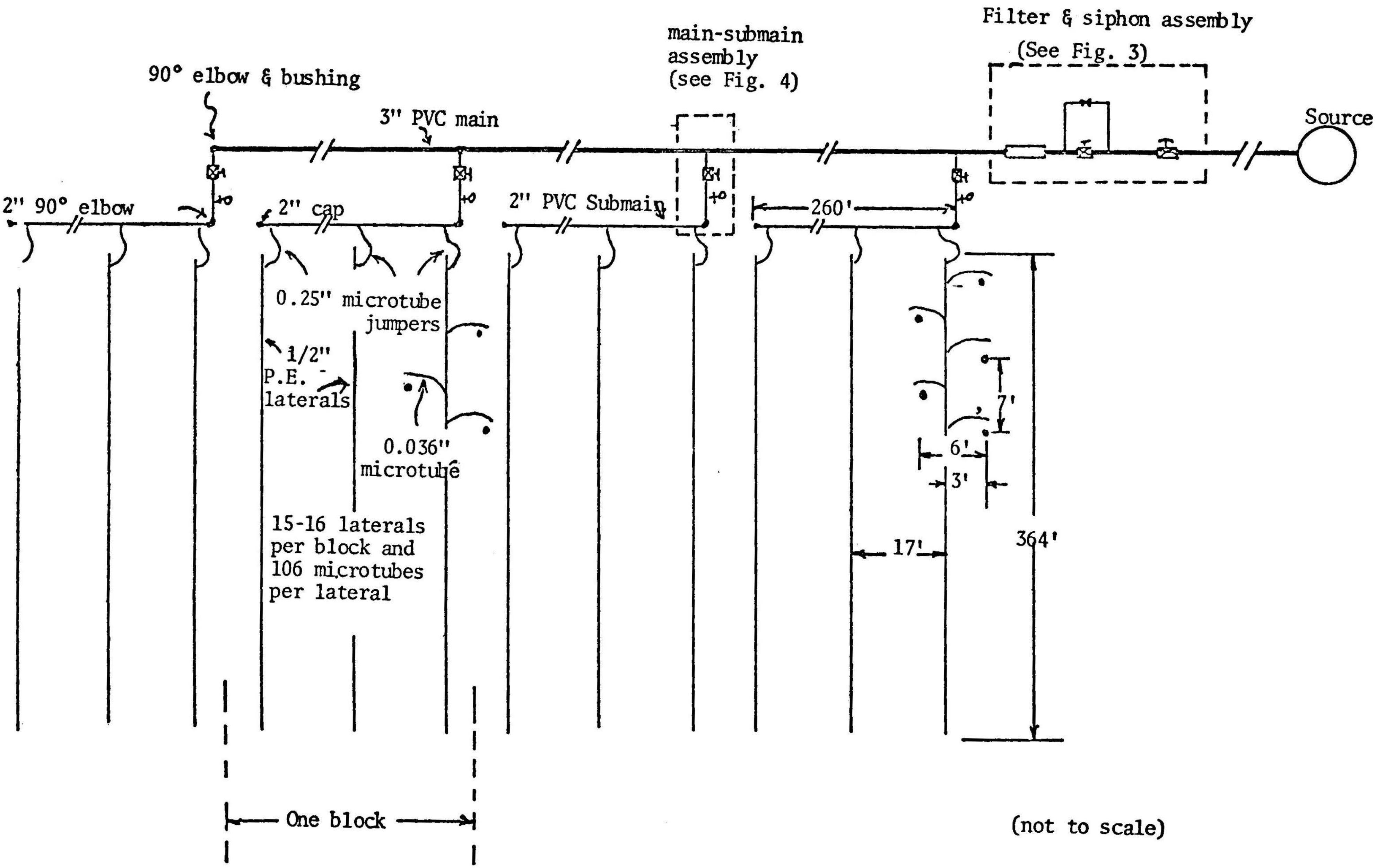

FIGURE 2. Irrigation System for 10 Acre Papaya Farm

Notes:

1. A pressure regulator (not shown here) Near the connection is recommended to maintain constant pressure to the farm.
2. All 1" sizes may be reduced to 3/4" without affecting performance.

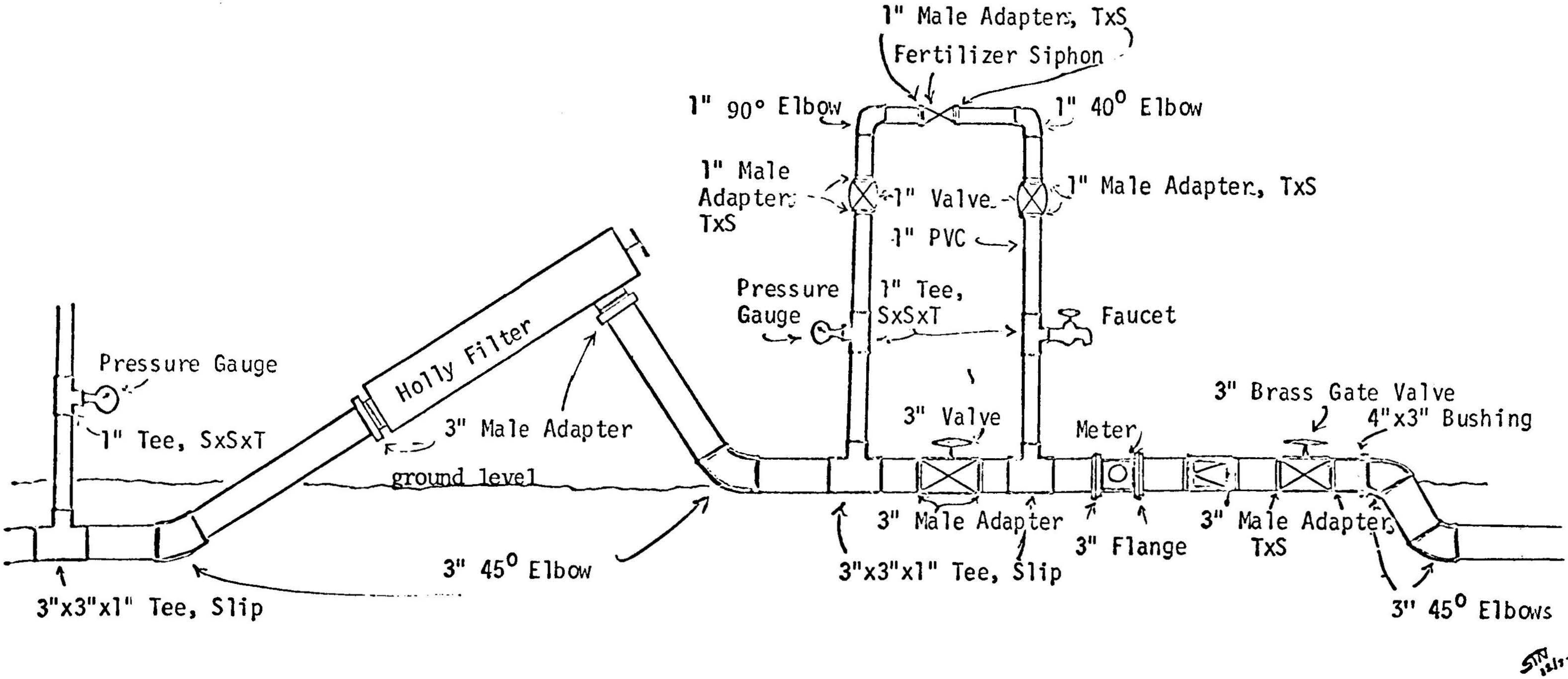

Figure 3. Filter-Siphon Assembly

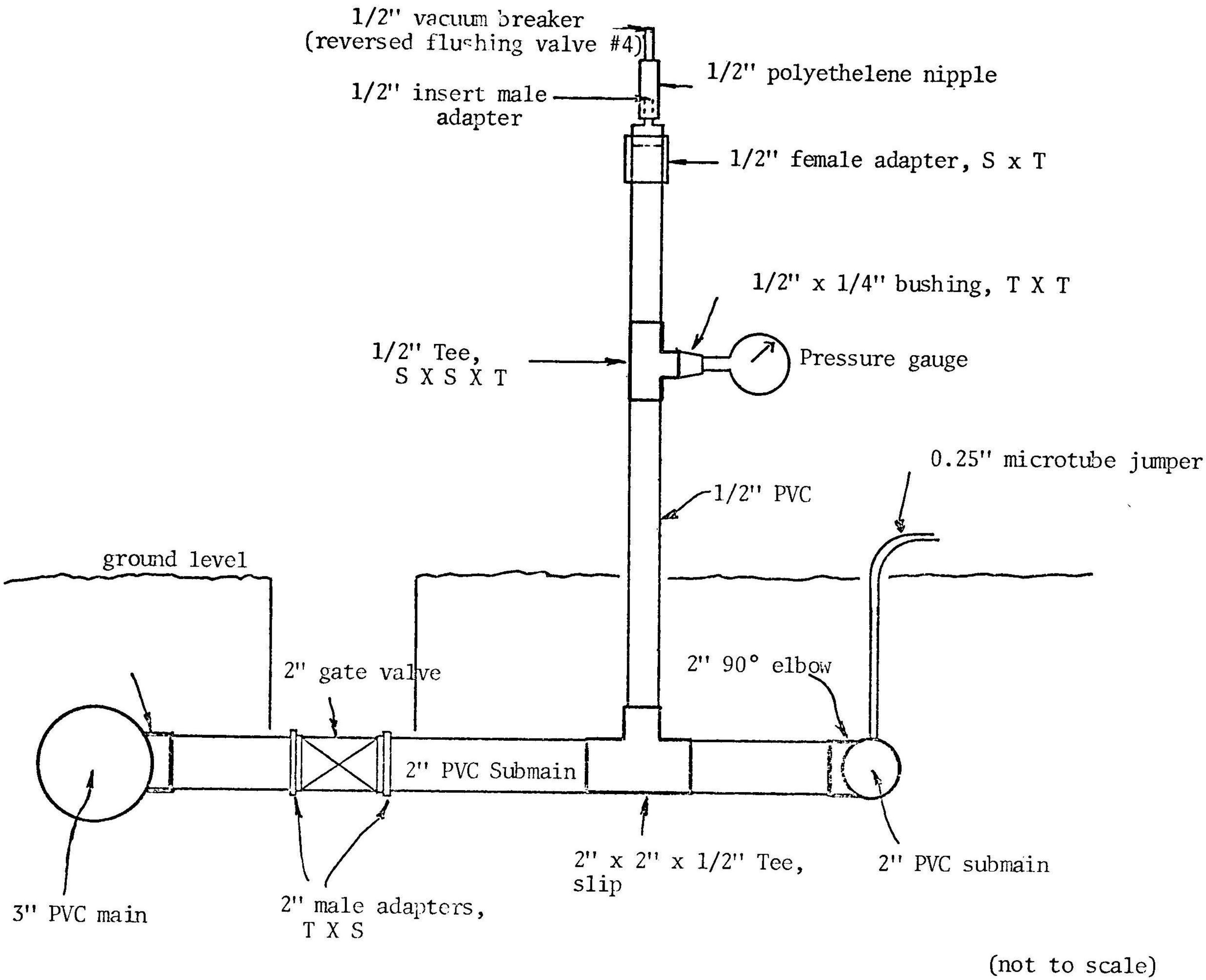

FIGURE 4. Main Submain Assembly

other end by a simple removable plug or a drain contraption for periodic flushing of the line. A single 0.036 inch microtube emitter about 4-5 ft. in length is used to irrigate a tree.

Since there is a total of 63 sets (and therefore laterals) in the 10 acres, each of the four submains serves between 15 to 16 laterals. Each lateral in turn irrigates 106 trees (two rows of 53 trees each). The length of each lateral is determined by the length of each row plus half of a tree spacing to allow for the staggered row ends. The computational formula for staggered row sets reduces simply to:

$$\begin{pmatrix}\text{length of}\\ \text{lateral}\end{pmatrix} = \begin{pmatrix}\text{tree spacing}\\ \text{within row}\end{pmatrix} \times \left[\frac{\text{trees}}{\text{row}} - \frac{1}{2}\right]$$

Thus, for our hypothetical farm:

$$\begin{pmatrix}\text{length of}\\ \text{lateral}\end{pmatrix} = 7 \times [53 - 0.5]$$

$$= 367.5 \text{ ft.}$$

COST CHARACTERISTICS AND ESTIMATES

The total cost of adopting a drip irrigation system for papaya production includes both the initial capital costs for materials and installation, and the subsequent recurrent costs of operating and maintaining the system. In order to combine and interpret these costs on a comparable basis, it is necessary to reduce the initial capital costs in annual equivalent terms. Also, for economic interpretation of these costs, it is useful to distinguish between those costs which are fixed versus variable with output for any given scale of operation. Current (1978) prices for materials and labor are used to develop the following estimates.

Capital Costs

Main and submain components. For any given scale of operations, the costs of the main and submain components can for all practical purposes be treated as fixed costs. These costs are essentially independent of tree spacings and number of trees per acre. Once the investment is committed, these sunk costs do not vary with papaya production per acre. Therefore, for any given farm of fixed acreage, these costs are short-run fixed costs and need not enter into economic calculations to optimize outputs per acre.

For different farm scales, however, these costs may be expected to vary in stepwise fashion as pipes, valves, and other component parts change with different capacity requirements. Thus, from the standpoint of long-run changes in farm scales, these costs are important considerations in determining the optimum economic scale of a drip irrigation system. Once such an optimum scale is established, however, these costs are fixed for that scale.

Laterals. The costs of laterals, on the other hand, may vary with output even for a given scale of operation. These costs are dependent upon tree spacings and the resultant trees per acre.

Within certain limits, papaya productivity is closely related to tree spacings and the number of trees per acre. The costs of laterals should therefore be variable with output within these limits even for fixed farm scales. These variable costs should be taken into account in all short-run production decisions.

For the long run, the prospects of technological improvements in laterals (including emitters, flushing valves, etc.) and in cultural practices have dominating influence. Since costs are likely to be highly sensitive to technological improvements, flexibility is an important design criterion for the laterals subsystem. This flexibility criterion can be met by reducing the time period over which the costs of laterals are sunk. This is a rational economic approach to allowing for future uncertainties. For papaya, under present cultural practices, an average production cycle of three years appears to be a reasonable economic life for the laterals.

Estimate of initial capital outlay. Estimating the initial capital outlay requirements for a drip irrigation system is complicated by a variety of factors. There is a wide variation of price lists for materials from different suppliers. Typically, each supplier's price list is further differentiated by customer categories. Each supplier has his own F.O.B. Honolulu price lists and separate discounts for plantations, co-ops, individual farmers and nonfarm customers. Prices also vary within each of these categories according to the volume of purchase. Plantations enjoy the largest discounts, then co-ops, individual farmers, and nonfarm customers, in that order. Customers on the neighbor islands must add freight shipment costs. The cost of installation can vary from one location to another. The requirements here mainly involve labor and tractor equipment for land preparation, laying out and connecting component parts, trenching and burying mains and submains, punching holes and connecting microtubing, and finally, testing and adjusting the system.

Notwithstanding the many variations that might be involved on the field, an initial capital cost requirement can be estimated for our 10-acre hypothetical farm. Based on the current F.O.B. Honolulu prices for farmers and reasonable labor and equipment charges for installation, the initial capital cost excluding taxes totals to around $4,500 or $450 per acre.

Tables 1 and 2 give summary breakdowns of these costs by subsystems and their respective material and installation requirements. A more detailed breakdown of the materials cost is given in Appendix A.

Annual Operating and Maintenance Costs

Water costs. Both fixed and variable charges are reflected in the cost of water. Fixed charges typically include standby charges, lease rentals for

Table 1. Initial Capital Investment Costs Per 10-Acres of Papaya

Item	Investment Cost	Percent
Main and submains		
Set-up costs		
Drill hole (submains) and installation	$526	11
Materials		
Main	682	15
Filter and siphon assembly	985	22
Submains	414	9
Gauges and air relief sets	47	1
Subtotal	$2,654	58
Laterals		
Set-up costs		
Preparation and installation	$ 400	9
Materials	1,483	33
Subtotal	$1,883	42
TOTAL	$4,537	100

Table 2. Costs of Installing a Drip Irrigation System for a 10-Acre Papaya Farm

Item	Unit	Quantity	Unit Cost	Total Cost
Main and submains				
Preparation and installation				
Labor (3 men for 3 days)	man-hour	72	$5	$370
One tractor and plow (2,000 ft. of trenching)	hours	16	6	96
Hole drilling (submain)	man-hour	12	5	60
Subtotal				$526
Laterals				
Preparation and installation				
Hole drilling and installing microtubings (2 men for 5 days)	man-hours	80	$5	$400
TOTAL				$926

water and its delivery systems, amortization costs for facilities, and so forth. Although these charges may vary with meter sizes, water system capacities, total acreages, and other scale factors, for a given farm scale the charges are fixed. They do not vary with the actual amount of water used and, therefore, the amount of papaya produced per acre.

Variable charges, on the other hand, result from water rates (usually expressed in cents/1,000 gals.) applied to the amount of water delivered. The rate may be constant for all levels of water delivered or it may increase or decrease in stepwise fashion at specified volumes.

For public water supplies, the fixed charges per customer are relatively small in comparison to the total variable charges. This is especially true for large water users such as farmers. In cases where water is supplied from self-service or other privately developed sources, the relationship between fixed and variable charges per user can be very different from large scale public water supply systems. For small private water systems, the fixed charges can be substantially higher than the total variable charges over a given period. This is especially true for small volume users of a water system designed to meet high peak loads and anticipated future growths in demand. In cases where high fixed charges must be distributed among a few existing users of the system, fixed charges can significantly influence long run economic decisions which determine the scale of farm operations.

Once a farm scale is selected, however, only the short-run variable costs need be accounted for in production decisions. These short-run variable costs depend primarily on the cost of power for pumping water.

To compute the short-run annual costs of water for our hypothetical farm, it is only necessary to know the total water requirement per acre and the water use rate charges. The annual water costs per acre can be computed as follows:

$$\left(\frac{\text{water costs}}{\text{acre/year}}\right) = \left[\left(\frac{\text{gallons}}{\text{tree/day}}\right) \times \left(\frac{\text{irrig. days}}{\text{year}}\right) \times \left(\frac{\text{tree}}{\text{acre}}\right)\right] \times \left(\frac{\$}{1{,}000 \text{ gals.}}\right)$$

If the water rate is a flat \$.20/1,000 gals, the annual water costs per acre to our farm would be:

$$\left(\frac{\text{water costs}}{\text{acre/year}}\right) = [8.0 \times 274 \times 667.8] \times \frac{.20}{1{,}000}$$

$$= \$293\text{/acre} \quad (\text{or } \$2{,}930\text{/10 acres})$$

or, on a per tree basis, roughly 44 cents per tree.

<u>Labor and maintenance costs</u>. There is no readily available data for estimating the labor and material requirements for operating and maintaining a drip irrigation system for papaya production in Hawaii. Also, it is difficult to separate out the labor cost for operating and maintaining the system since these functions are to a large extent carried out simultaneously.

In general, labor requirements are fairly low for drip irrigation systems and are provided in conjunction with other routine work around the farm. Time must be devoted to working the fertilizer-siphon assembly and the four sub-main valves according to set schedules, to periodically flushing the laterals, and to checking for leaks and proper functioning of the microtube emitters, vacuum breakers, and other operating parts of the system.

If any leaks or malfunctioning of parts are detected, then both labor and material may be required for the repair and maintenance of the system. For the most part, the repair or replacement of malfunctioning parts can be handled by trained farm labor. A typical routine task would be to replace malfunctioning microtube emitters.

Based on the limited experience to date, a reasonable estimate of the hourly requirements might be around one-half hour for each irrigation day at about $5 per hour. Then the annual labor cost per acre can be computed as follows:

$$\left(\frac{\text{labor costs}}{\text{acre/year}}\right) = \left(\frac{1}{\text{total acres}}\right) \times \left[\left(\frac{\text{hours}}{\text{irrig. day}}\right) \times \left(\frac{\text{irrig. days}}{\text{year}}\right)\right] \times \left(\frac{\text{wage}}{\text{hour}}\right)$$

$$= \frac{1}{10} \times [(0.5 \times (274)] \times (5.00)$$

$$= \$68.50/\text{acre} \qquad (\text{or } \$685/10 \text{ acres})$$

Material costs for maintenance and repair can be based on a recent study by Wilson, et al., (1976) for citrus orchards in Arizona. In this study, the annual material costs for maintenance and repair was estimated at around $7.60 per acre (or $76 per 10 acres). A similar experience might be expected for our 10-acre papaya farm.

<u>Summary results of annual operating and maintenance costs</u>. Table 3 summarizes the results on a 10-acre farm basis. Total annual operating and maintenance costs are around $3,690, of which 98 percent will be for irrigation water and labor. The major share (79 percent) of these costs is for water requirements. Only a relatively minimal expenditure (2 percent) will be required for maintenance and repair.

Total Annualized Use Costs

The initial lump-sum capital costs must first be expressed in annual equivalent terms before they can be combined with the annual operating and

Table 3. Annual Operating and Maintenance Costs Per 10 Acres

Item	Quantity	Rate	Costs	Percent
Water (1,000 gals.)	14,638	$0.20	$2,928	79
Labor (man hours)	137	5.00	685	19
Maintenance and repair (material)	-	-	76	2
TOTAL			$3,689	100

Table 4. Total Annualized Use Costs Per 10 Acre Papaya Farm

Cost Items ($)	Useful Life (Yrs)	Annual Depreciation Costs ($)	Annual Interest Costs ($) @ 9%	Total Annualized Use Costs ($)	Percent of Total (%)
Capital					
Main and Submain ($2,654)	20	$133	$119	$252	5.4
Laterals ($1,883)	3	628	85	713	15.3
Operating and Maintenance ($3,689)	-	-	-	3,689	79.3
TOTAL				$4,654	100.0

maintenance costs. This can be done by applying the following formulas to the capital costs of the various sub-system components. The results will approximate the amortized annual costs reflecting both depreciation and interest costs.

$$\text{Depreciation costs} = \frac{\text{(Material and installation costs)}}{\text{(Useful life)}}$$

$$\text{Interest costs} = \frac{\text{(Material + installation costs) x (annual interest rate)}}{2}$$

A 9 percent prevailing annual interest rate was used in the results shown in Table 4. The total annualized use costs amount to approximately \$465 per acre. Operating and maintenance costs account for almost four-fifths of the total since water is the main cost of the fully functioning system.

The amortized capital cost for the system as a whole (\$965) is only about one-fifth of the total cost. This is mainly accounted for by the laterals subsystem (15 percent of total annual costs). The main and submain subsystems, including their affiliated filter and siphon assembly, gauges, and air relief sets, account for only a small portion (5 percent) of the total annual use cost.

A federal cost-sharing program for drip irrigation practices applies only to this 5 percent portion of the total cost. Under the cost-sharing rule of this program, if 75 percent of the capital costs of the integrated main and submain subsystem were to be covered by the federal government, the growers share would be reduced to around \$189 per year for the 10 acres (i.e., \$18.90 per acre) or about 4 percent of the total annual use costs. The relatively high cost of laterals and operating and maintenance would have to be fully assumed by the grower.

GENERALIZED FORMULA

A generalized procedure for computing the annual use costs per acre can now be expressed as follows:

$$\begin{bmatrix}\text{total annualized}\\ \text{use costs per acre}\end{bmatrix} = \begin{bmatrix}\text{main \& submain (i=1)}\\ \text{annualized capital}\\ \text{depreciation \& inter-}\\ \text{est costs per acre}\end{bmatrix} + \begin{bmatrix}\text{laterals (i=2)}\\ \text{annualized capital}\\ \text{depreciation \&}\\ \text{interest costs per acre}\end{bmatrix}$$

$$+ \begin{bmatrix}\text{annual water}\\ \text{costs per acre}\end{bmatrix} + \begin{bmatrix}\text{annual labor}\\ \text{costs per acre}\end{bmatrix} + \begin{bmatrix}\text{annual maintenance}\\ \text{costs per acre}\end{bmatrix}$$

This can be specified more precisely as follows:

$$\frac{TAUC}{Acre} = \left(\frac{1}{TA}\right) \left\{ \sum_{i=1}^{2} \left[\left(\frac{C_i}{L_i}\right) \times \left(1 + \frac{R \times L_i}{2}\right) \right] + [GPTD \times IDY \times TPA \times WR] \right.$$

$$\left. + \quad [IDY \times LHID \times LHW] \quad + [M] \right\}$$

where:

$\frac{TAUC}{Acre}$ = total annualized use cost per acre

T_A = total acres

C_i = capital costs for materials and installation ($)
subscript i=1: main and submain
i=2: laterals

L_i = useful life (years)
subscript i=1: main and submain
i=2: laterals

R = annual interest rate

GTPD = gals per tree per day water requirement

IDY = irrigation days per year

TPA = trees per acre

WR = water rate ($/1,000 gals)

LHID = labor hours per irrigation day-labor requirement

LHW = labor hourly wage rate ($/hr)

M = maintenance, material costs

To apply this formula to our hypothetical 10-acre farm, it is convenient to adopt the following data format:

Variables	Symbol	Data
Total acres	TA	10
Trees per acre	TPA	667.8
Capital Costs		
Main and submain:		
Material plus installation ($)	C_1	2,654
Useful life (years)	L_1	20

Variables	Symbol	Data
Laterals:		
Material plus installation ($)	C_2	1,883
Useful life (years)	L_2	3
Annual interest rate	R	0.09
Operations & Maintenance Costs		
Water:		
Gals/tree/day	GPTD	8.0
Irrig. days/year	IDY	274
Water rate	WR	0.20/1,000
Labor:		
Hrs/irrig. day	HID	0.5
Wage rate ($/hr)	HW	5
Maintenance:		
Material costs ($/yr)	M	76
Total Annual Use Cost (Computed as shown below)		
Per acre ($)	TAUC/acre	465.32
Per tree ($)	TAUC/tree	0.70

The results as shown on the two bottom lines are then easily computed as follows:

$$\frac{TAUC}{acre} = \left(\frac{1}{10}\right) \times \left\{ \left[\left(\frac{2654}{20}\right) \times \left(1 + \frac{.09 \times 20}{2}\right)\right] + \left[\left(\frac{1,883}{3}\right) \times \left(1 + \frac{.09 \times 3}{2}\right)\right] + [8 \times 274 \times 6,678 \times .20/1,000] + [274 \times .5 \times 5] + [76] \right\}$$

$$= \frac{1}{10} \{252.13 + 712.40 + 2,927.64 + 685 + 76\}$$

$$= \$465.32/acre$$

$$\frac{TAUC}{tree} = \frac{465.3}{667.8} = \$.70/tree$$

Sensitivity Analysis

With the aid of this generalized formula, we can test the sensitivity of costs to various wet and dry growing conditions. Supplemental irrigation days in different growing areas of Hawaii may vary from about 90 percent (329 days of the year) for very dry areas to around 10 percent (37 days) for very wet areas. The daily water requirements per tree may vary between 6-10 gals. (i.e. ± 25 percent of our 8 gals). Water rates may range from $.10/1,000 gals to $.40/1,000 gals (i.e. by half to twice as much as our $.20/1,000 gals).

Table 5. Total Annualized Use Costs Per Acre Under Wet and Dry Growing Conditions for 10-Acre Farms with 667.8 Trees Per Acre

Variables	Baseline	Extreme Values: Wet Area (10% Supplement irrig. days)	Extreme Values: Dry Area (90% Supplement irrig.days)
Water Requirements			
Irrig.days/year	274	37	329
Gals/tree/day	8.0	6.0	10.0
Water Rate			
$/1,000 gals	0.20/1,000	0.10/1,000	0.40/1,000
Total Annualized Use Costs			
$/acre	$465	$128	$1,065
$/tree	$ 0.70	$ 0.19	$ 1.59

Table 5 shows the computed extreme values relative to our hypothetical baseline conditions. Under the various wet and dry growing conditions of the islands, the annualized use costs may be between 28 percent ($128/acre) to 229 percent ($1,065/acre) of our hypothetical baseline of $465/acre.

Automation

Automation of the entire system can be easily accomplished by replacing the four 2-inch manual valves in the submains with similar sized automatic valves (e.g. battery operated Water Watcher valves). The change in annual use cost of such a conversion depends upon the difference in costs of the valves and the associated effects on water, labor, and maintenance costs.

Two-inch sized Water Watcher valves are available at around $167 apiece as compared to $17 per manual valve. The total difference in initial capital cost for four replacement valves amounts to $600. The annual equivalent of this difference is computed by the generalized formula (assuming equal useful lives) to be $5.70/acre (or $57/10 acres).

The cost of operating the Water Watcher valve itself is minimal. A standard D-sized flashlight battery is used to power the timer mechanism which operates from one-half hour to 10 hours everyday or every other day. The service life of each battery is about a year.

A trouble-free automated system can promise savings in water and labor costs. More timely and controlled application of water is possible, and labor for operating manual valves is released for other purposes. On the other hand, full automation may have its disadvantages if removing direct managerial involvement in the practice of irrigation also lessens direct involvement in other associated farm management practices. Close surveillance of an automated system need not be less than for a manually operated system.

Power Costs and Water Rates

Water rates are primarily dependent upon the cost of pumping water which, in turn, is determined by the cost of power. If water rates increase proportionately with increases in power costs, and if fuel oil prices are expected to increase at about 5-8 percent annually, then the present water rates can be expected to double within 9-14 years. Thus, if the current water rate for our hypothetical farm is $.20/1,000 gallons, this rate can be expected to double to $.40/1,000 gallons in about a decade to a decade and a half.

Since the cost of water is the major cost item in any irrigation system, the anticipated escalation on water rates with power costs can be expected to have a major influence in the rate at which drip irrigation systems will be adopted. The fixed differentials in technical irrigation efficiences between alternative furrow irrigation practices will be magnified by the increasing cost of water over time.

Further, this economic advantage of drip irrigation can be expected to be compounded by the additional benefits of increased productivities and associated reductions in the costs of labor, fertilization, and pest control.

SUMMARY

This report presents baseline information and computational procedures for estimating the cost of drip irrigation for papaya farming in Hawaii. A drip irrigation system consisting of main, submain, and lateral components is designed for a hypothetical 10-acre farm. Tree density on this farm is computed at 667.8 trees per acre and an average daily water requirement of 8.0 gals per tree is used. The initial capital cost and subsequent annual operation and maintenance costs are estimated based on 1978 prices and actual field experiences. Economic flexibility is built into the system through different time horizons over which the costs of the different components are sunk. The buried main and submain components have an average useful life of approximately 20 years. The less durable surface laterals need replacement after each production cycle, which averages around 3 years. The effect of these differential economic time horizons is to increase the annual use cost of the laterals relative to that of the main and submain components.

The initial capital cost, including outlays for materials and installation, amounts to approximately $454 per acre. At an interest rate of 9 percent, and with the differential time horizons, this initial cost reduces to an annual equivalent of around $96 per acre. Adding this to an annual operation and maintenance costs of $369 per acre for water, labor, and replacement materials (other than laterals) raises the total annualized use cost of the system to $465 per acre.

The capital costs of the buried main and submain components can be cost-shared with the Federal Government under the Agricultural Conservation and Stabilization program. If 75 percent of this portion were to be paid by this program, the annual benefit to the farmer would be less than $19 per year or around 4 percent of the total annual use cost. The remaining 96 percent, including the high annual costs of laterals and operations and maintenance, would still be assumed by the farmer.

The most important operation and maintenance cost-item is water. But the conditions that determine the physical requirements for water and its unit-cost vary from place to place and over varying time periods. Thus, a generalized cost-estimating formula is developed and used to test the sensitivity of the total annualized use-cost to different papaya growing conditions in the state. The results suggest that the annual costs may vary over a wide range of extreme values, from as low as $128 per acre to as high as $1,065 per acre. The generalized formula can be applied to any specific set of conditions. In any case, the unit-cost of water is of prime concern, and the economic prospects for drip irrigation weigh heavily on the cost of electric power that is ultimately reflected in the cost of water to farmers.

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APPENDIX A

MATERIALS LIST AND COSTS

Component	Quantity	Unit Price (Dollars)	Total (Dollars)	Percent (%)
Main				
3" PVC Pipe (class 160)	925 ft.	$60.22/100 ft.	$557.04	
3" 45^{o} elbow, SxS	4	3.78	15.12	
3" gate valve	1	48.03	48.03	
3" flow Meter	1	43.90	43.90	
3" male adapter, TxS	8 (4)*	2.22	17.76	
Subtotal			$681.85	18.9
Filter & Fertilizer Siphon Assembly (Fig. 3)				
Holly filter 250 GPM	1	$364.00	$364.00	
3" gate valve	1*	48.03	48.03	
3" backflow valve	1*	440.00	440.00	
3"x3"x1" tee, slip	3 (2)*	4.43	13.29	
1" PVC pipe (class 160)	20	14.06/100 ft.	2.81	
1" tee, SxSxT	3 (1)*	.63	1.89	
1" male adapter, TxS	6*	.36	2.16	
1" gate valve	2*	5.63	11.26	
Fertilizer siphon	1*	78.00	78.00	
Faucet	1*	3.92	3.92	
Pressure gauge, 0-60 psi.	2 (1)*	8.25	16.50	
1" vacuum breaker	1	3.20	3.20	
Subtotal			$985.06	27.3
Submain				
3"x3"x2" tee, slip	3	$ 4.43	$ 13.29	
3" 90^{o} elbow, SxS	1	3.78	3.78	
2" PVC Pipe (class 160)	1,120 ft.	27.54/100 ft.	308.45	
2" 90^{o} elbow, SxS	8	1.23	9.84	
3"x2" bushing	1	1.35	1.35	
2" end cap, slip	4	.56	2.24	
2" gate valve	4	17.03	68.12	
2" male adapter, SxT	8	.90	7.20	
Subtotal			$414.27	11.5

*Fertilizer siphon system.

Component	Quantity	Unit Price (Dollars)	Total (Dollars)	Percent (%)
Gauges & Air Relief Sets (Fig. 4)				
2"x2"x1/2" tee, slip	4	1.46	5.84	
1/2" tee, SxSxT	4	.30	1.20	
1/2"x1/4" bushing, TxT	4	.41	1.64	
Pressure gauge, 0-60 psi	4	8.25	33.00	
1/2" female adapter, SxT	4	.20	0.80	
1/2" insert male adapter, TxS	4	.20	0.80	
1/2" PVC	15 ft.	8.45/100 ft.	1.27	
1/2" flushing valves	4	.63	2.52	
Subtotal			$47.07	1.3
Laterals				
0.25" microtube	126 ft.	$25/1000 ft.	$ 3.15	
1/2" polyethylene pipe	23,153 ft.	5.40/100 ft	1,250.26	
0.036" microtube (bulk roll)	30,051 ft.	50.60/8000 ft.	190.07	
1/2" drain valves	63	.63	39.69	
Subtotal			$1,483.17	41.0
SYSTEM TOTAL			$3,611.42	(100%)

Freight Costs

The added costs of shipping the irrigation material from Honolulu to the neighbor islands can be computed by applying the following Young Brothers, Ltd. freight rates to the cargo measured in weight or volume (1 cu. ft. = 50 lbs.).

Irrigation Material	Unit	Hawaii	Maui & Kauai
Plastic, rigid	Per 2,000 lbs.	$32.71	$32.42
Plastic, flexible	Per 40 cu. ft.	9.92	9.35
Nonspecified cargo	Per 2,000 lbs. or 40 cu. ft.	18.35	17.21

These rates include insurance, public service tax and state wharfage charges.

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